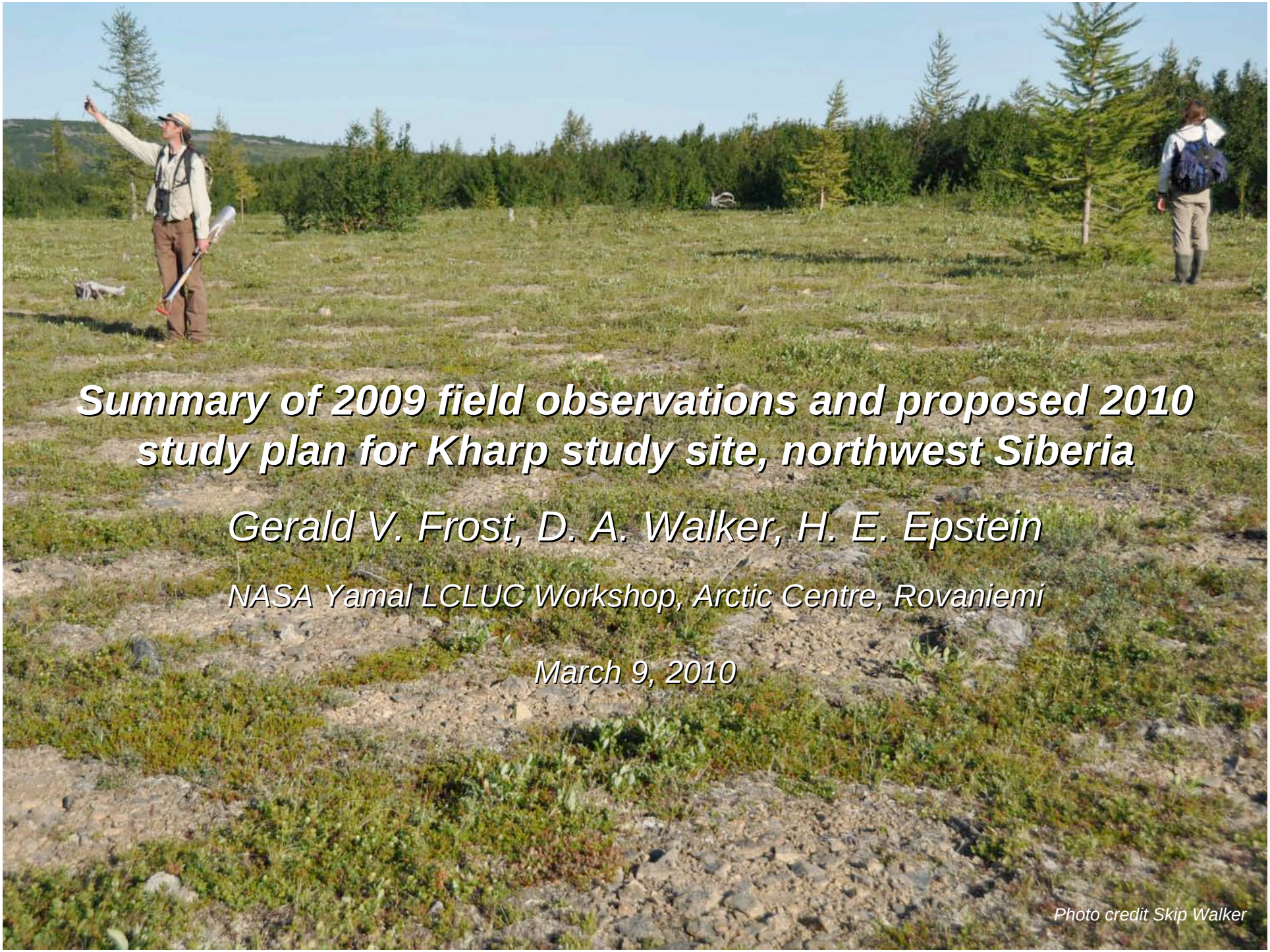


Summary of 2009 field observations and proposed 2010 study plan for Kharp study site, northwest Siberia

Gerald V. Frost, D. A. Walker, H. E. Epstein

NASA Yamal LCLUC Workshop, Arctic Centre, Rovaniemi

March 9, 2010

Photo credit Skip Walker

Presentation Outline

1. Dissertation background
2. Kharp study area
   - Location and proximity to Yamal Transect
   - Satellite photo comparisons: 1968 and 2003
3. Field observations at Kharp – 1 August 2009
4. Methods used to quantify changes in shrub and tree abundance based on the satellite record
5. Relating landscape heterogeneity and changes in vegetation structure to the NDVI metric
6. Summary of scientific questions and proposed field methods

Dissertation Background

- There is mounting evidence that shrubs and trees are expanding in the North American Low Arctic...
    - repeat photography (Tape et al. 2006, Jorgenson et al. 2007)
    - plot-level field studies and experiments (e.g., Chapin III et al. 2005)
- …but data for northern Eurasia are few.
    - vast, remote remote region
    - dendrochronology studies suggest pulses of tree recruitment in northwest Siberia over the last ~60 years (Esper and Schweingruber 2004, Shiyatov et al. 2005)
- Remote sensing indicates increased productivity (NDVI) in much of the Pan-Arctic, but interpretation is difficult.

Dissertation Background

- The Pan-Arctic is becoming warmer and the abundance of trees and shrubs has increased in some areas, but the ubiquity of this response is unclear.
- Changes to ecotonal vegetation are difficult to detect using widely-used remote sensing data.
  - Inadequate spatial resolution
  - Inadequate period of record
  - Ambiguity of NDVI record
  - Historical aerial photography difficult to obtain for Russia
- Declassified high-resolution Corona and Gambit satellite photography extends the period of record to the mid-1960s.

Dissertation Chapters

1. Quantify changes in the spatial extent of tall shrub and tree cover since the 1960s at ~15 ecotonal sites distributed across the Pan-Arctic, using comparisons of high-resolution satellite photography.
2. Assess the relative importance of local and regional-scale environmental factors as drivers of observed changes.
3. Evaluate the relationship between changes in the cover and structure of vegetation and the NDVI metric.

Imagery Sources

Historical

Corona (1967 – 1972)
- panchromatic
- 2 m spatial resolution

Gambit (1963 – 1967)
- panchromatic
- 75 cm spatial resolution

Contemporary

Quickbird (2001 – present)
- R, G, B, NIR
- 60 cm spatial resolution

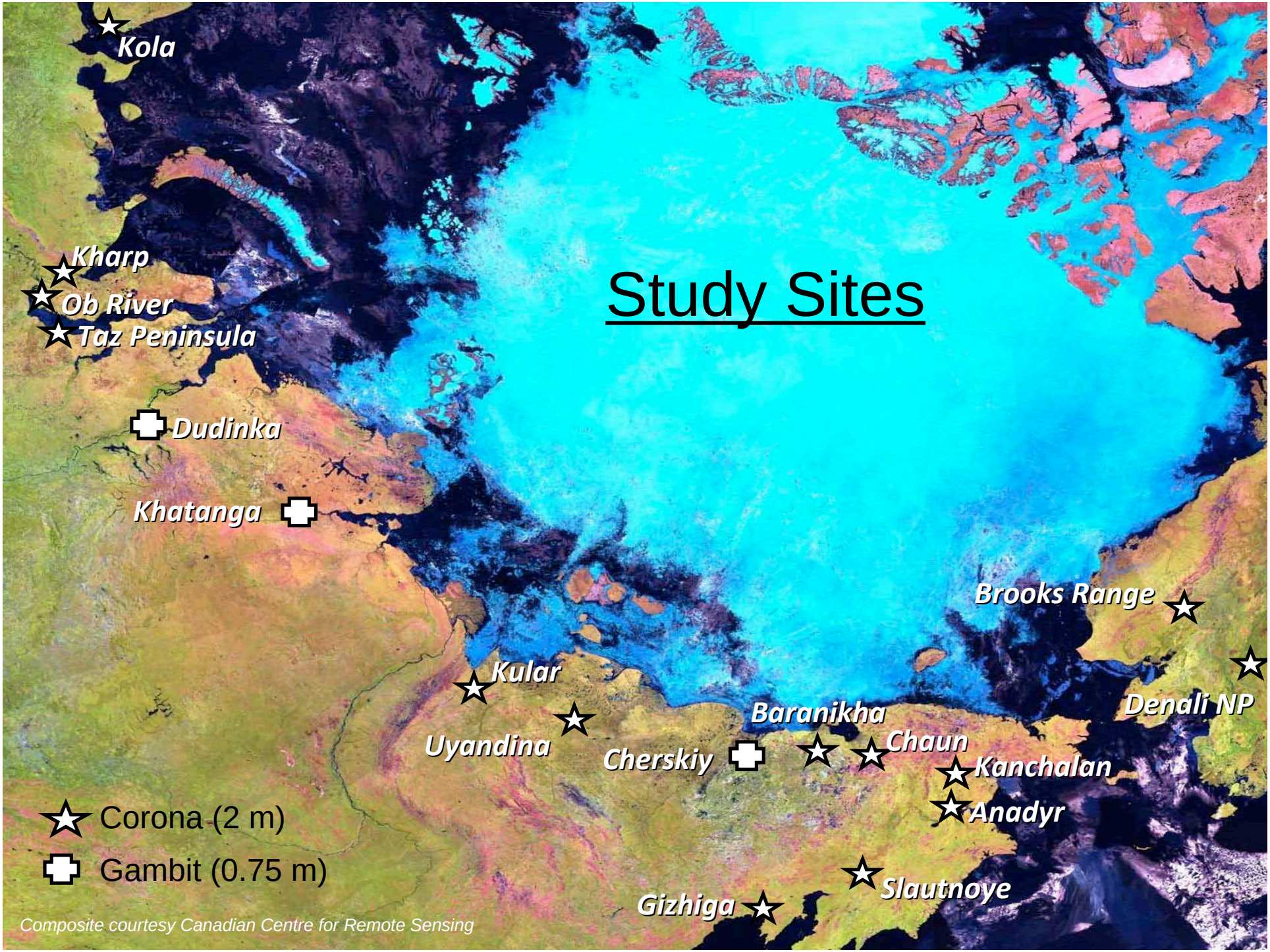
IKONOS (1999 – present)
- R, G, B, NIR
- 80 cm spatial resolution

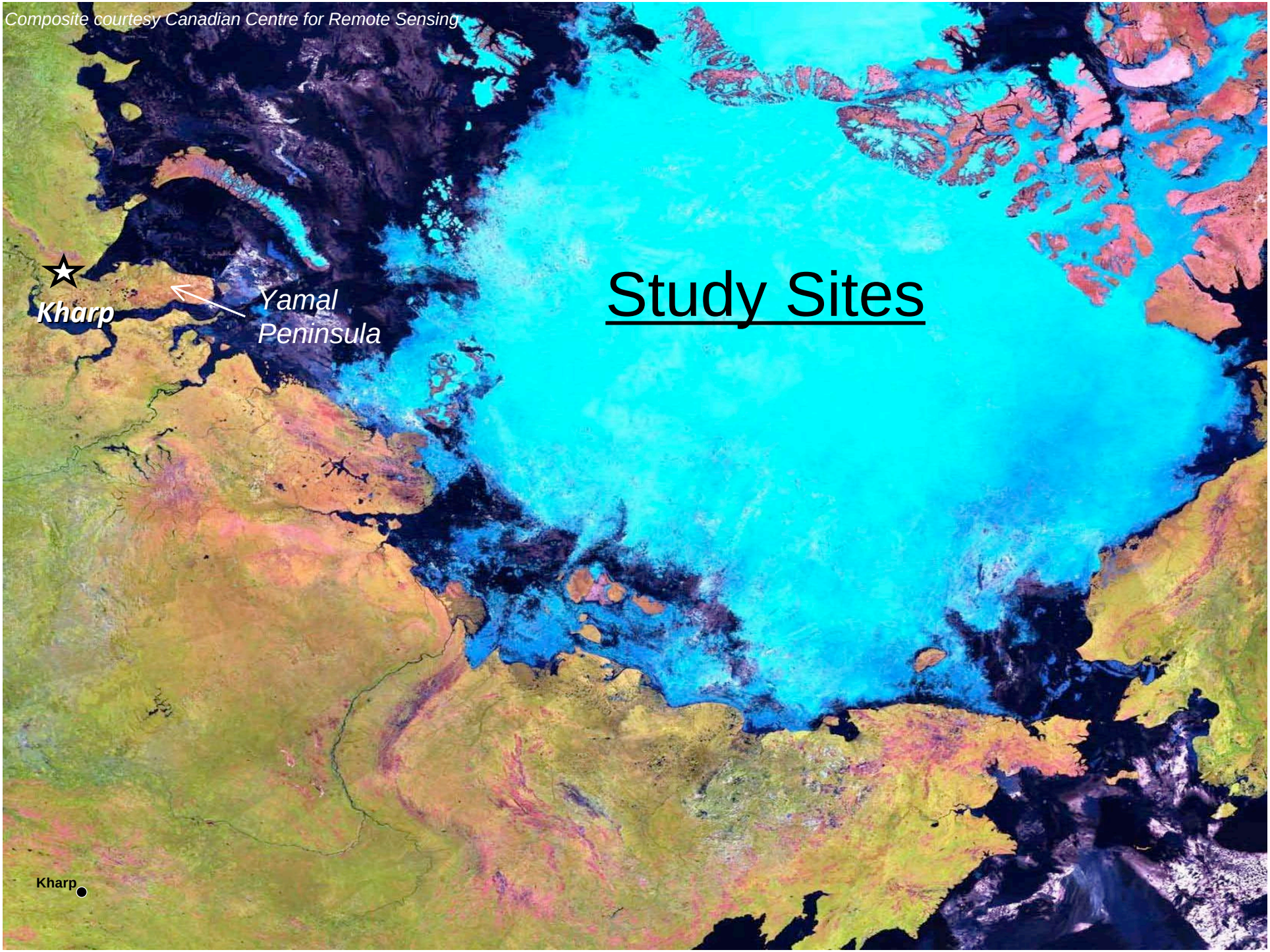
Worldview-1 (2007 – present)
- panchromatic
- 60 cm spatial resolution

Federation of American Scientists 1997

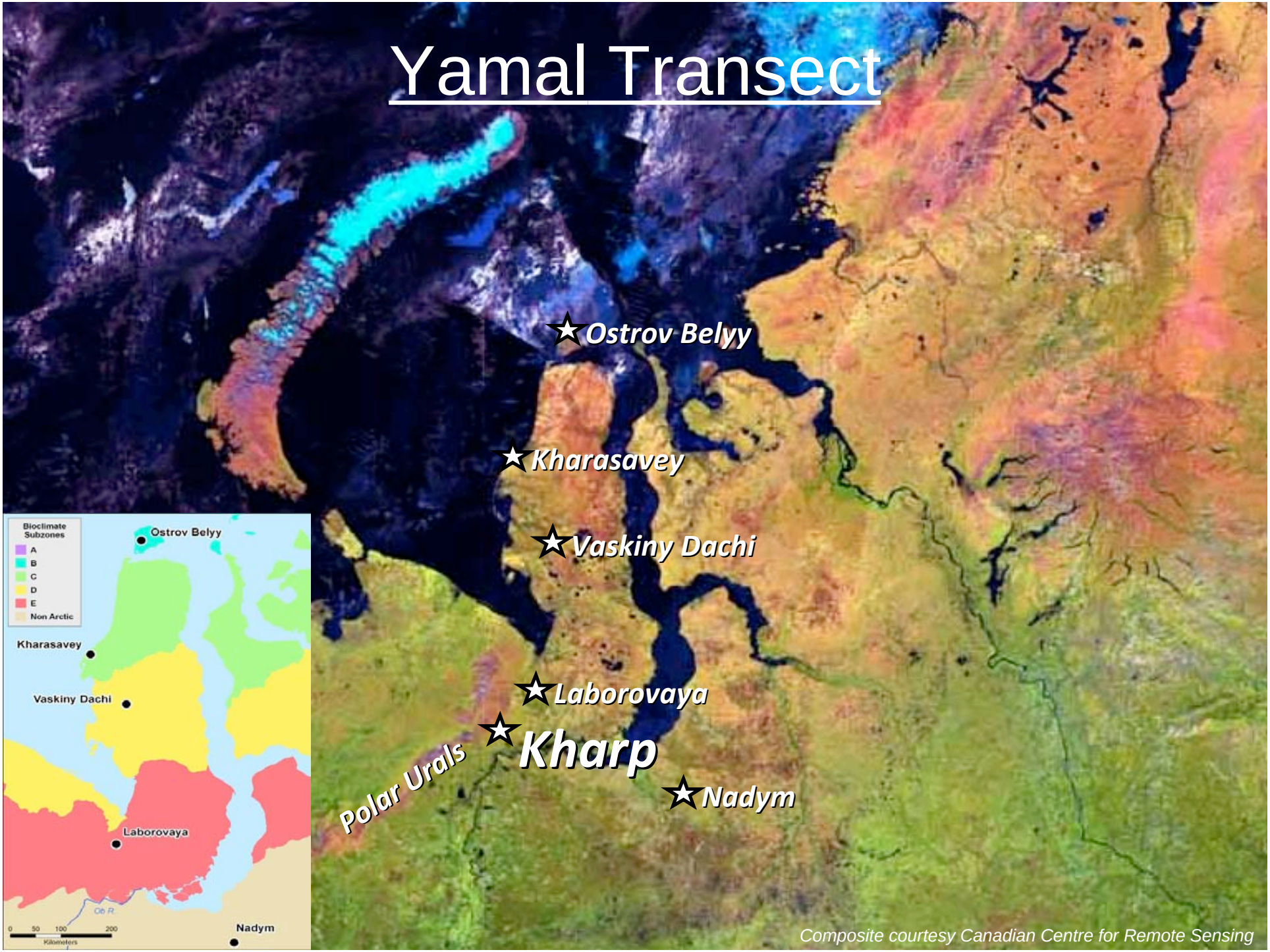
- **Cold War-era surveillance heralded beginning of modern remote sensing**
- **worldwide coverage**
- **high spatial resolution (0.75 – 2 m)**
- **allows detection of land-cover changes over ~45 year timescale**

CORONA LAUNCH & RECOVERY SEQUENCE


Study Sites
Kola
Kharp
Ob River
Taz Peninsula
Dudinka
Khatanga
Brooks Range
Denali NP
Kular
Uyandina
Baranikha
Chaun
Cherskiy
Kanchalan
Anadyr
Slautnoye
Gizhiga
Corona (2 m)
Gambit (0.75 m)
Composite courtesy Canadian Centre for Remote Sensing

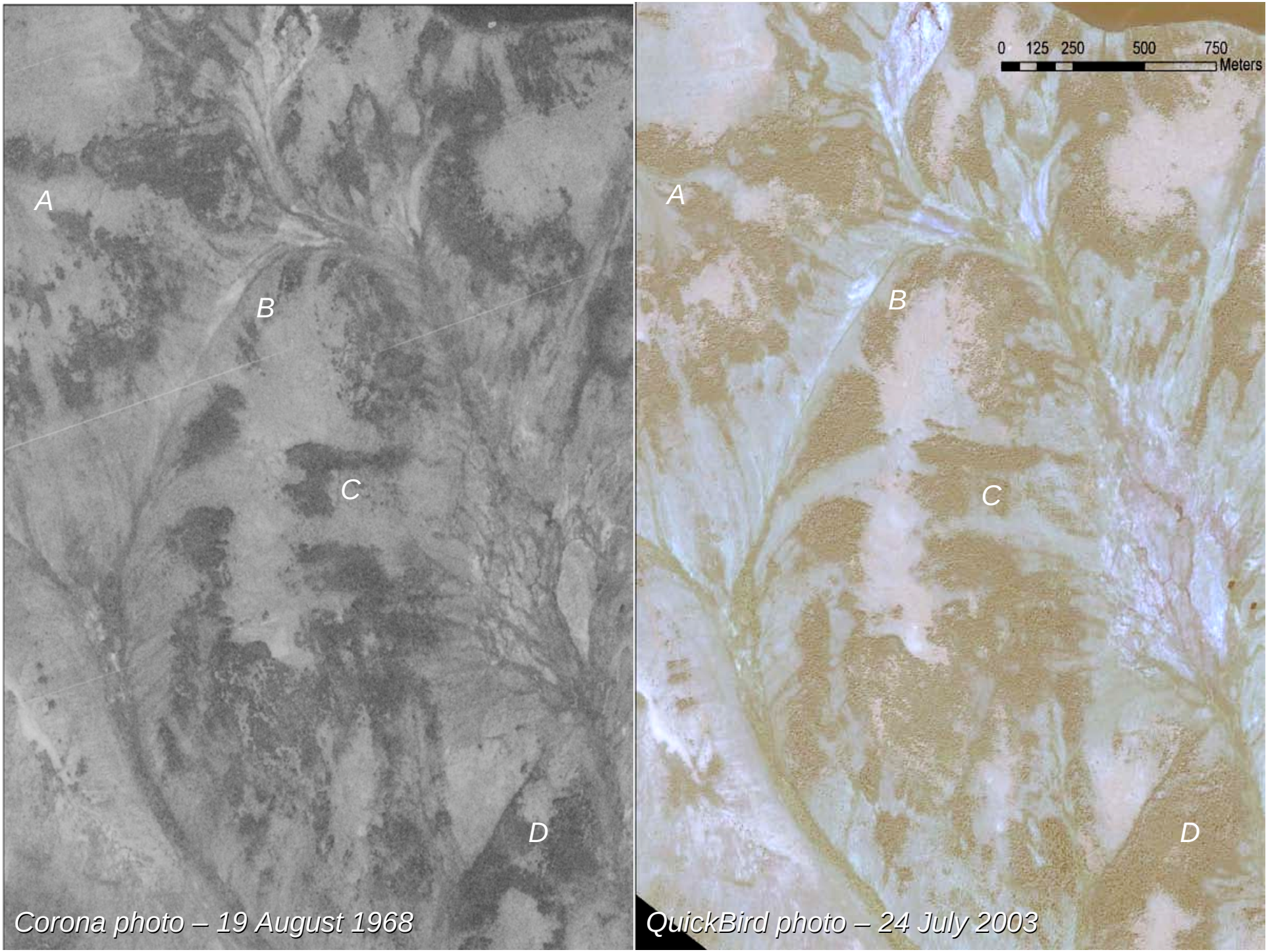

Composite courtesy Canadian Centre for Remote Sensing
Kharp
Yamal Peninsula
Study Sites
Kharp

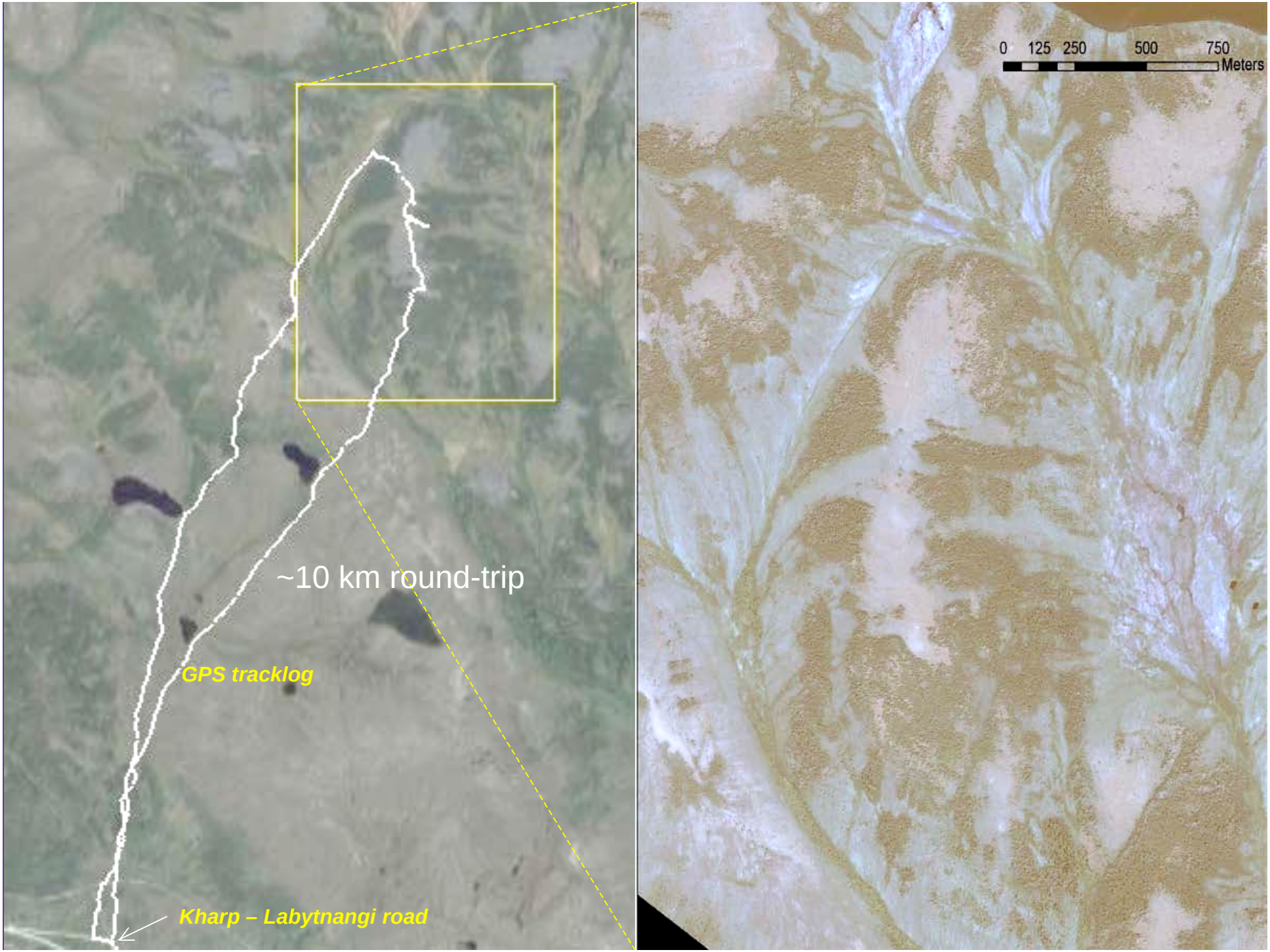
Yamal Transect



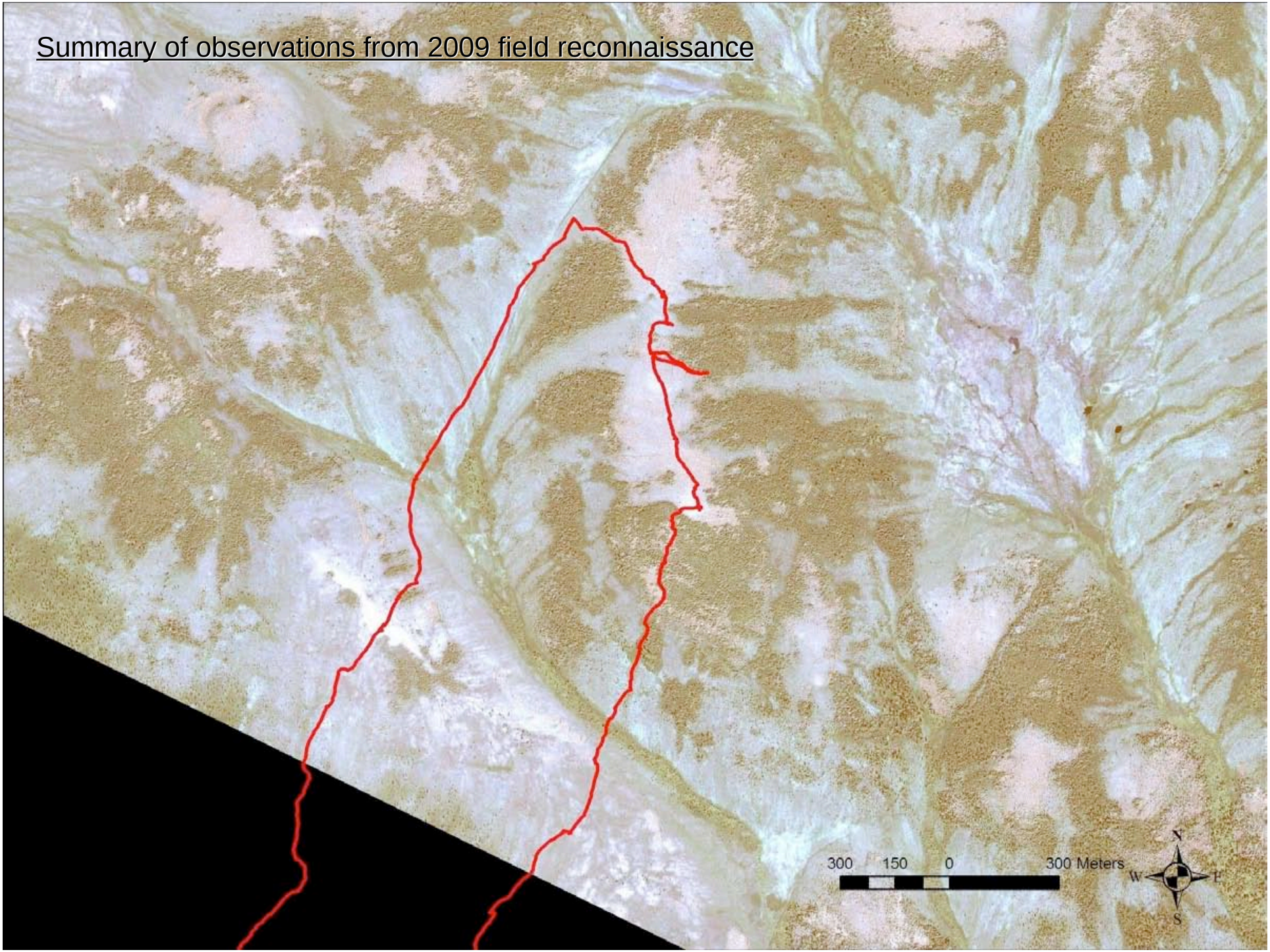
Corona photo – 19 August 1968

QuickBird photo – 24 July 2003


A
B
C
D
Corona photo – 19 August 1968
0 125 250 500 750
Meters
A
B
C
D
QuickBird photo – 24 July 2003


~10 km round-trip
GPS tracklog
Kharp – Labytnangi road
0 125 250 500 750
Meters

Summary of observations from 2009 field reconnaissance



Summary of observations from 2009 field reconnaissance

1. **Much of the region was affected by an intense wildfire ~100 yrs ago**


Photo credit Skip Walker


Photo credit Skip Walker

300 150 0 300 Meters

N W E S

Summary of observations from 2009 field reconnaissance

1. Much of the region was affected by an intense wildfire ~100 yrs ago
2. **Sorted- and non-sorted circles are common**

Photo credit Ronnie Daanen

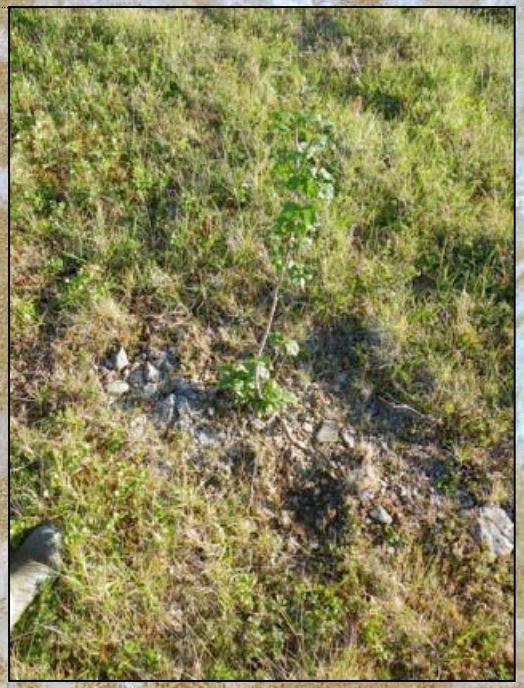
Photo credit Ronnie Daanen

300 150 0 300 Meters

N W E S

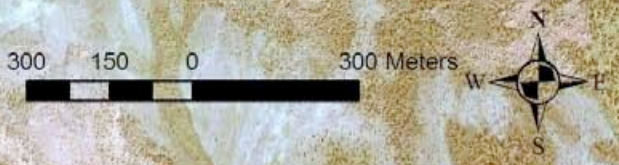
Summary of observations from 2009 field reconnaissance

1. Much of the region was affected by an intense wildfire ~100 yrs BP
2. Sorted- and non-sorted circles are common
3. **Recent alder recruitment appears to be closely linked to sites where mineral-dominated edapahic conditions were created or maintained by wildfire and cryogenic disturbance.**



Summary of observations from 2009 field reconnaissance

1. Much of the region was affected by an intense wildfire ~100 yrs BP
2. Sorted- and non-sorted circles are common
3. Recent alder recruitment appears to be closely linked to sites where mineral-dominated edapahic conditions are created by wildfire and cryogenic disturbance.
4. **Mature Siberian larches are uncommon, except where dense alder stands likely served as firebreaks.**

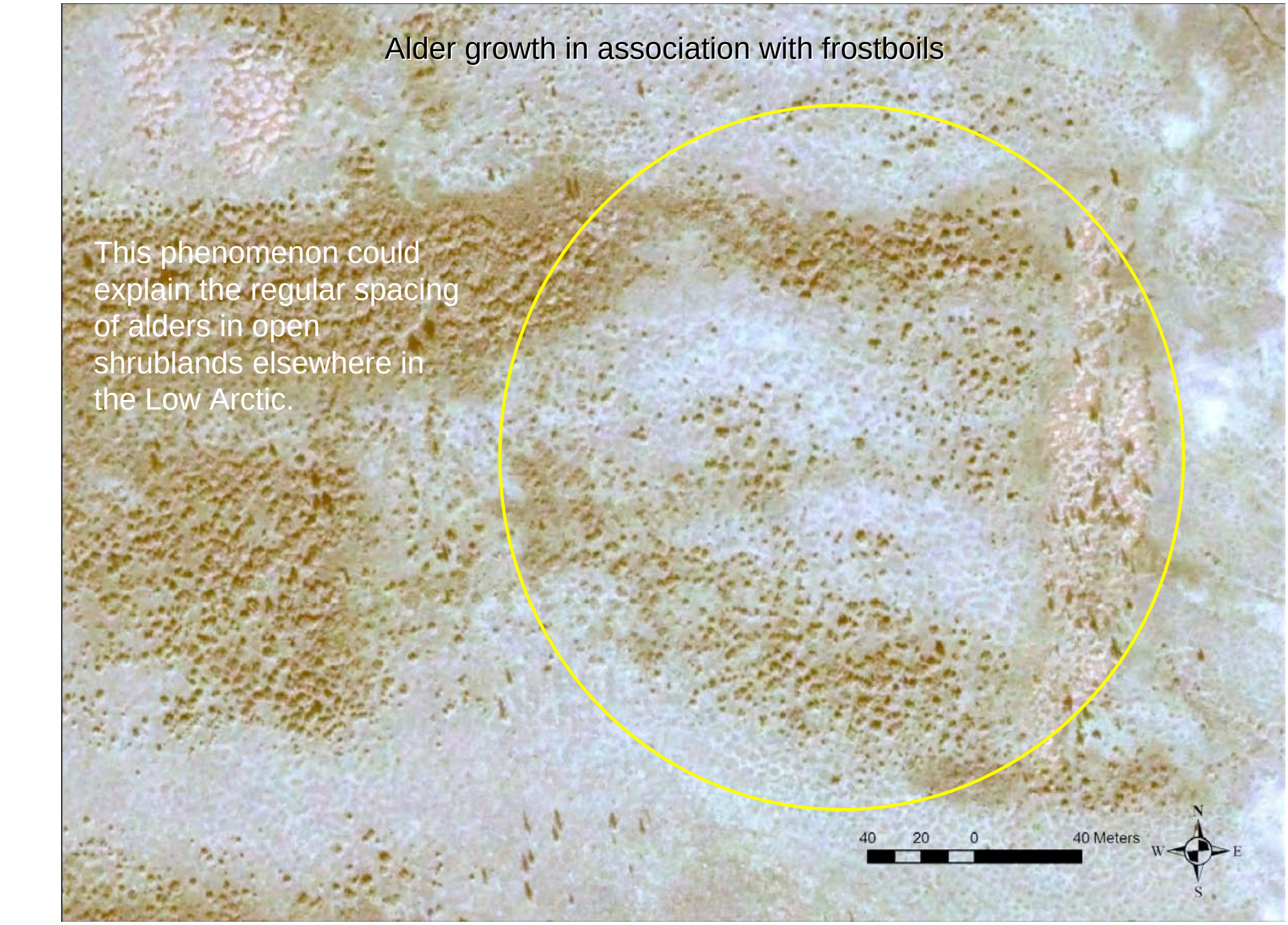


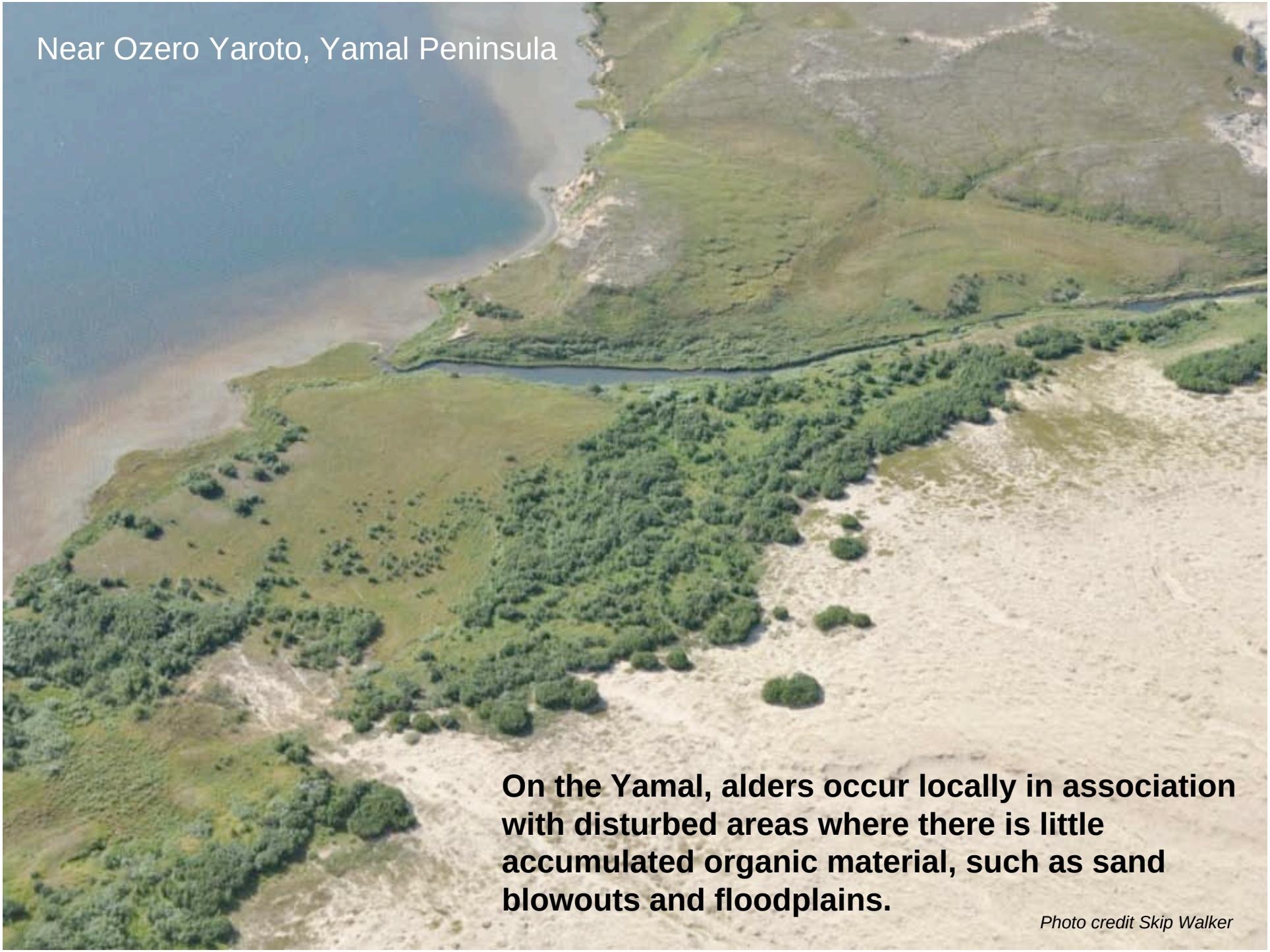

Field observations indicated that alder recruitment is concentrated on mineral-dominated frost-boils, where cryogenic disturbance prevents the formation of an organic mat. This could explain the regular spacing of shrubs in open alder shrublands of the Low Arctic.
Photo credit Skip Walker


Alders are generally minerotrophic and are common in primary succession (e.g., Schalin 1967). Their high relative growth rates probably allow them to become established on frost boils, whereas typical tundra vegetation cannot.
Photo credit Skip Walker

Alder growth in association with frostboils

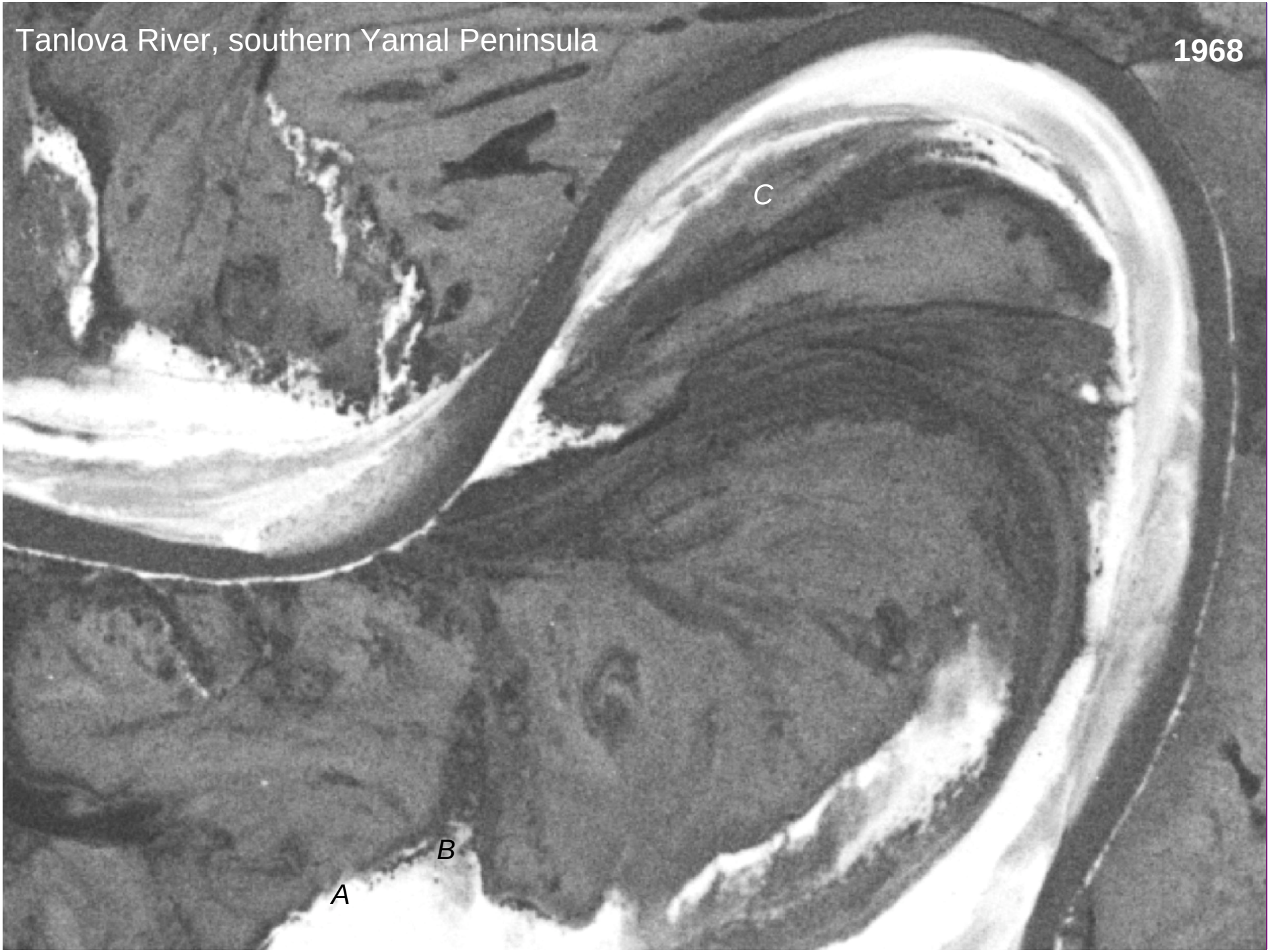
This phenomenon could explain the regular spacing of alders in open shrublands elsewhere in the Low Arctic.



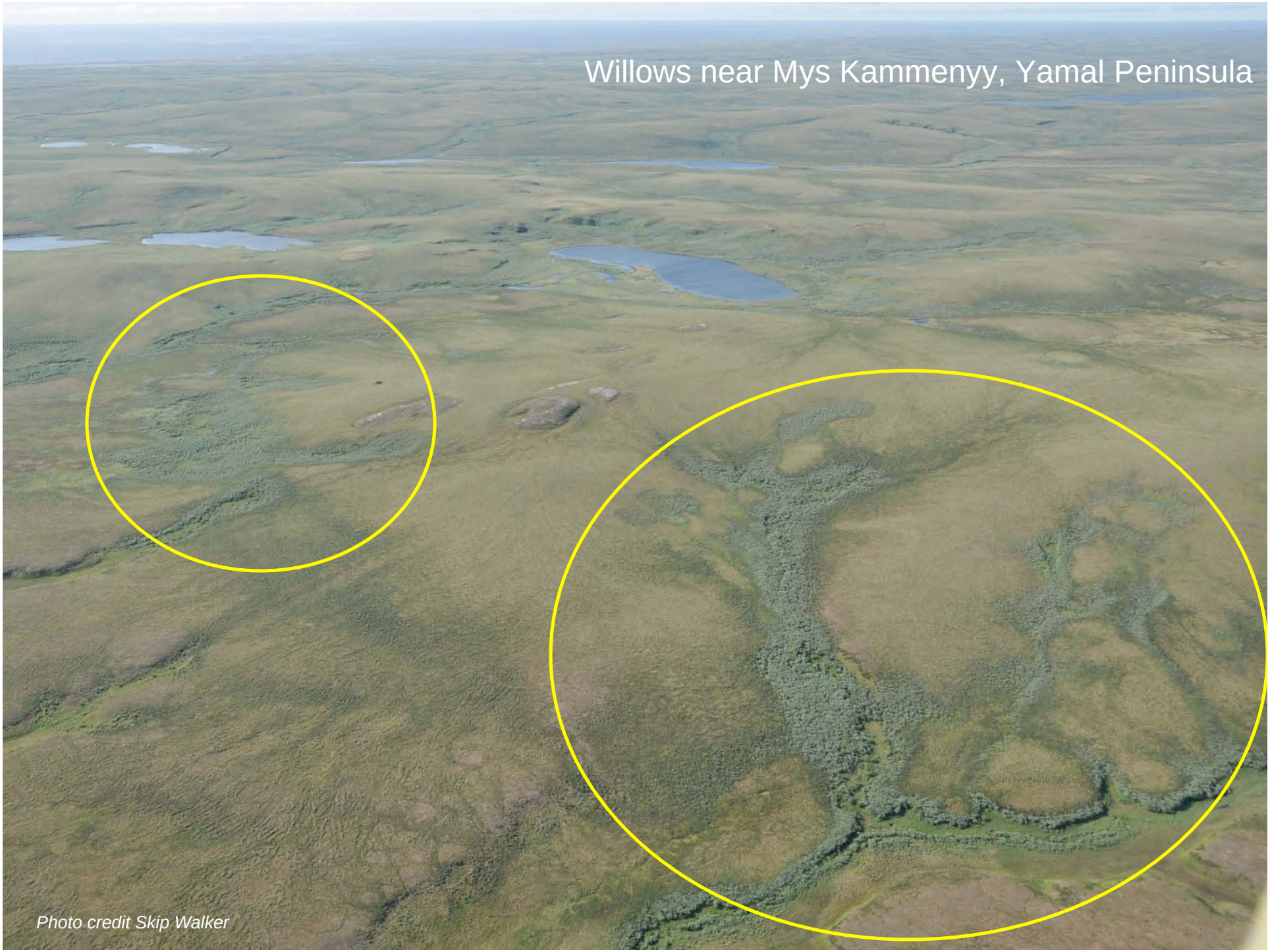


On the Yamal, alders occur locally in association with disturbed areas where there is little accumulated organic material, such as sand blowouts and floodplains.

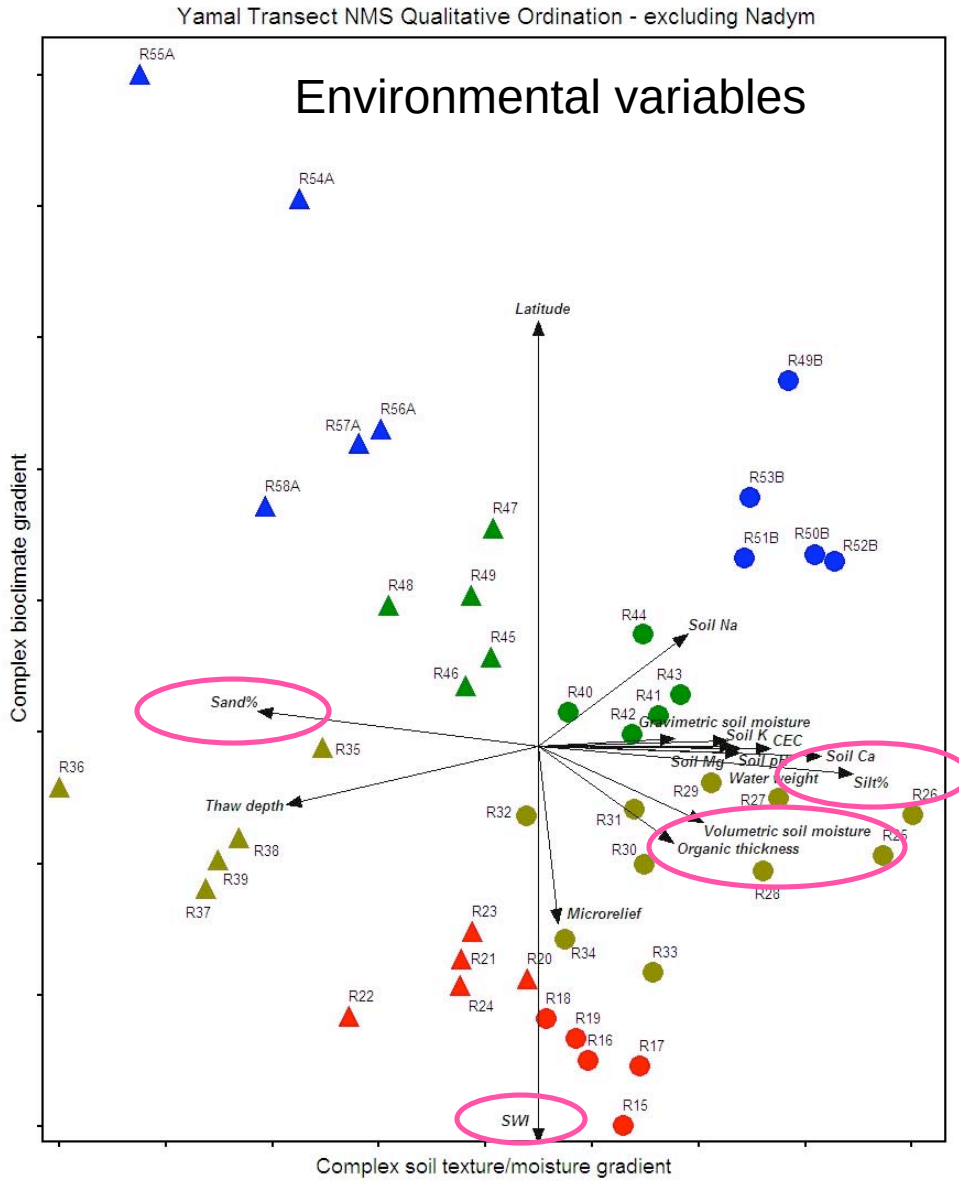
Photo credit Skip Walker

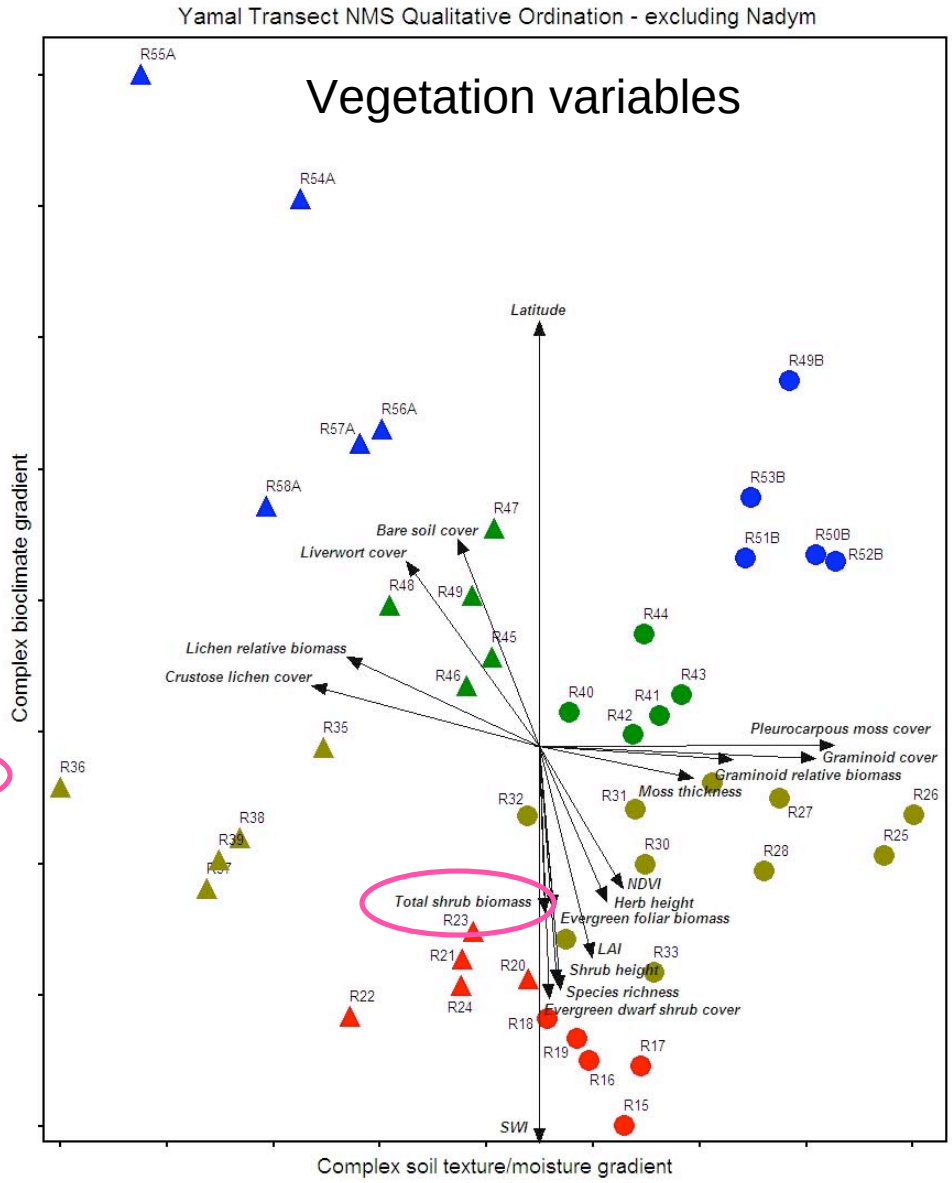

Tanlova River, southern Yamal Peninsula
1968
C
B
A


Tanlova River, southern Yamal Peninsula
2009
C
B
A
Photo credit Skip Walker


Willows near Mys Kammenyy, Yamal Peninsula
Photo credit Skip Walker

What are the key environmental affinities for shrubs in the Arctic, and how do these vary by species?

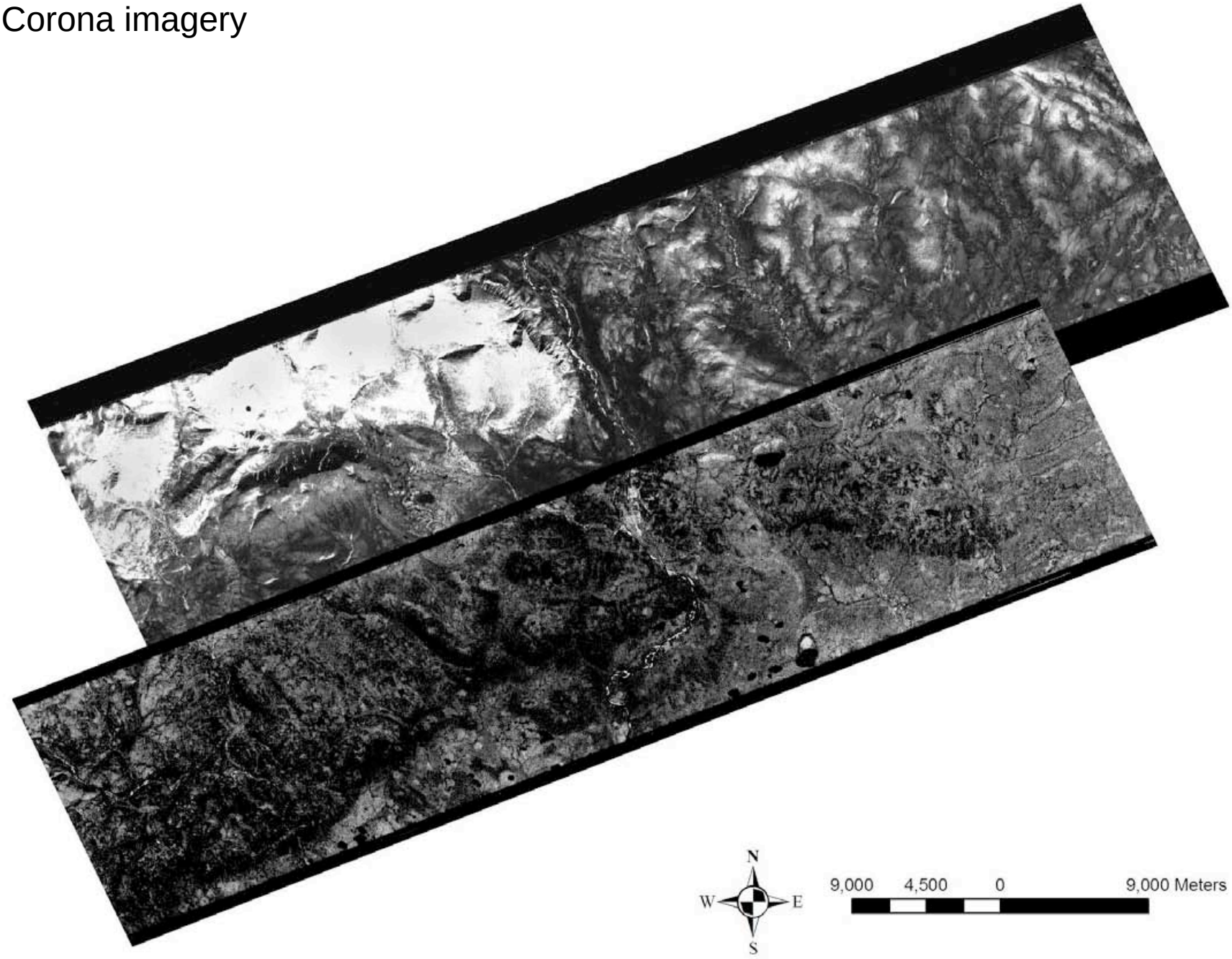




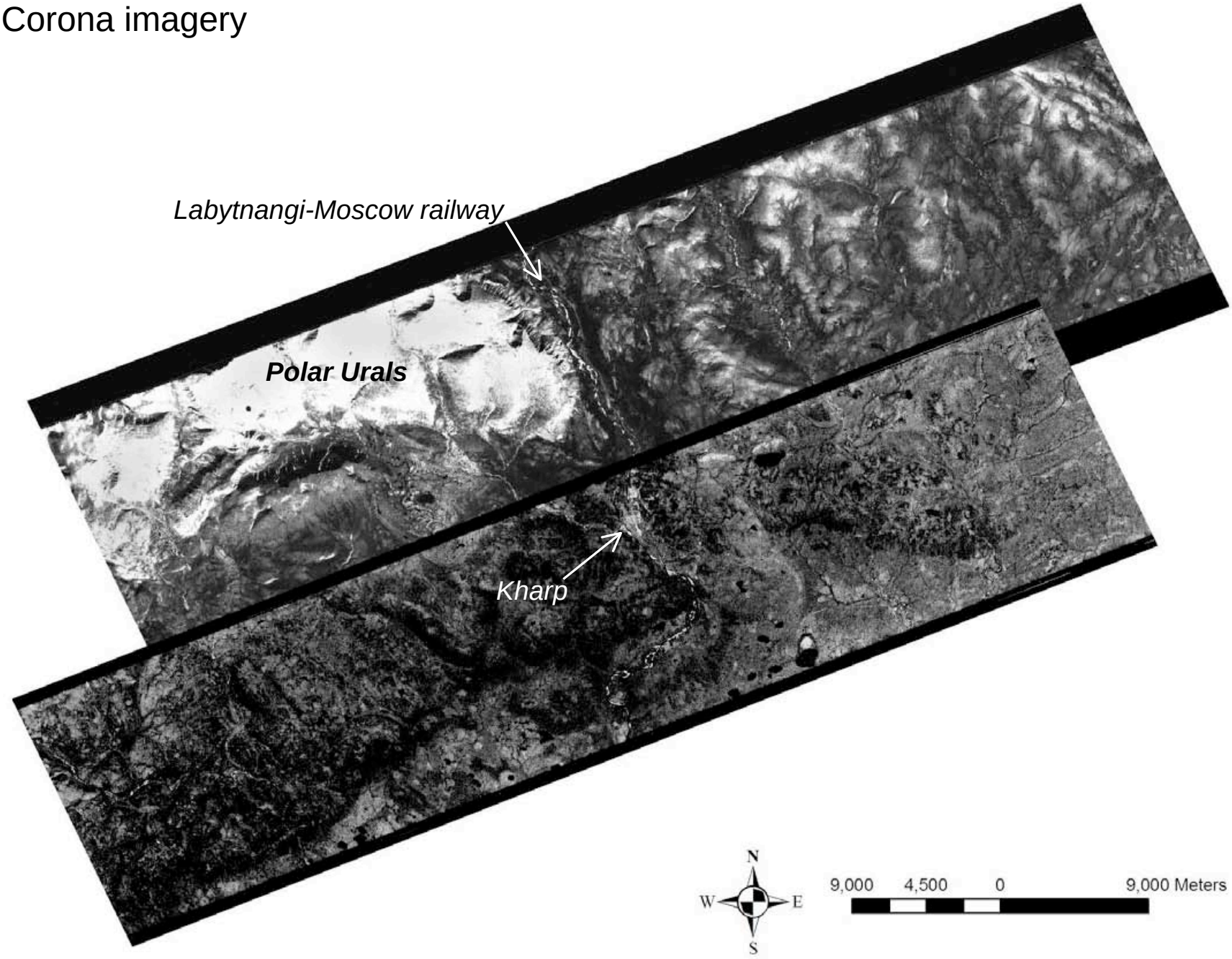
Vegetation Classification and Metrics using Satellite Imagery

- A simple vegetation classification system will be used that relates vegetation structure to characteristic photo-signatures in satellite photography.
- Using a point-intercept sampling approach, determine:
  - absolute change of shrub and tree cover (m^2)
  - relative change of shrub and tree cover (%)
- Field data will facilitate interpretation of the changes in vegetation that are evident in the satellite imagery

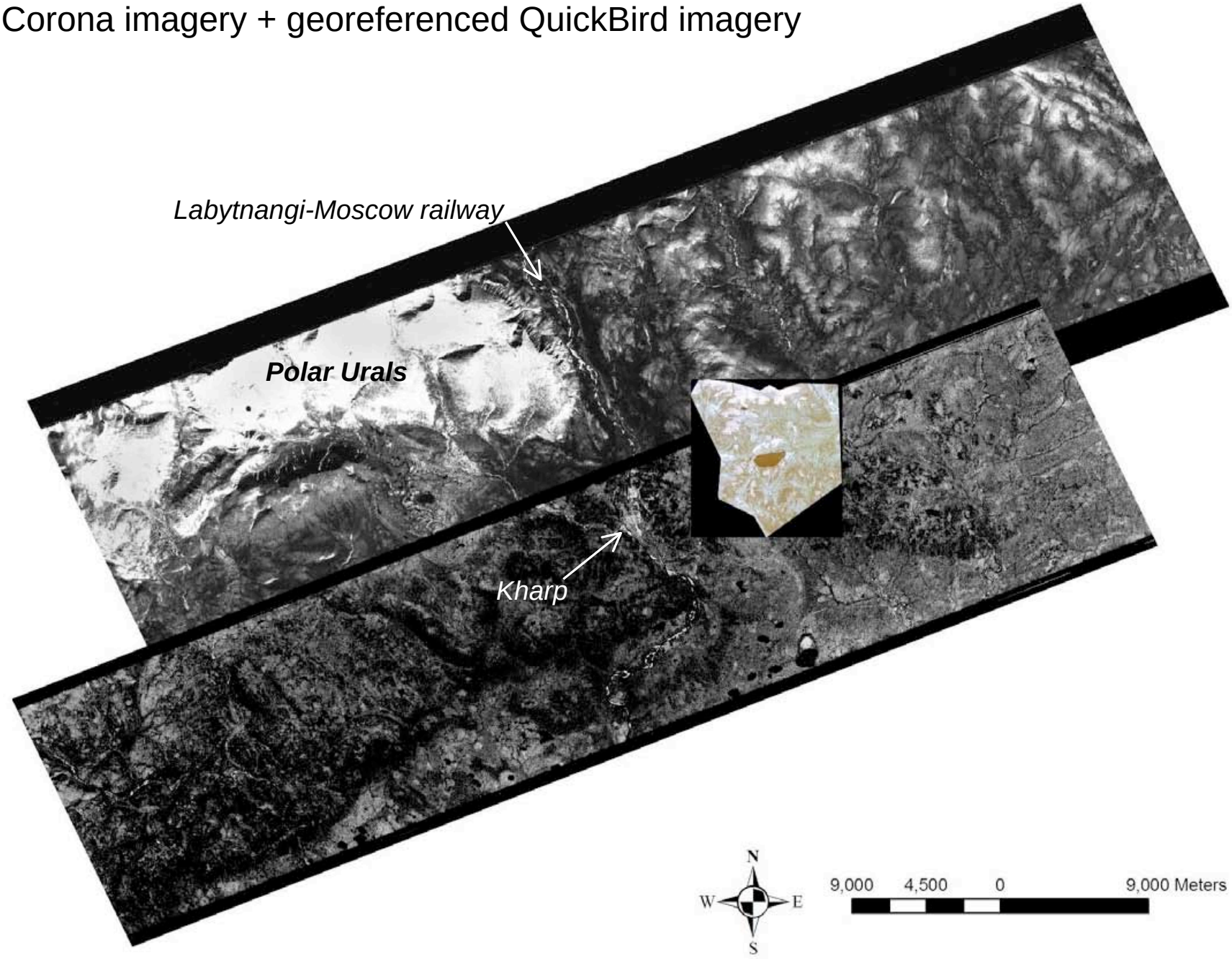
Corona imagery

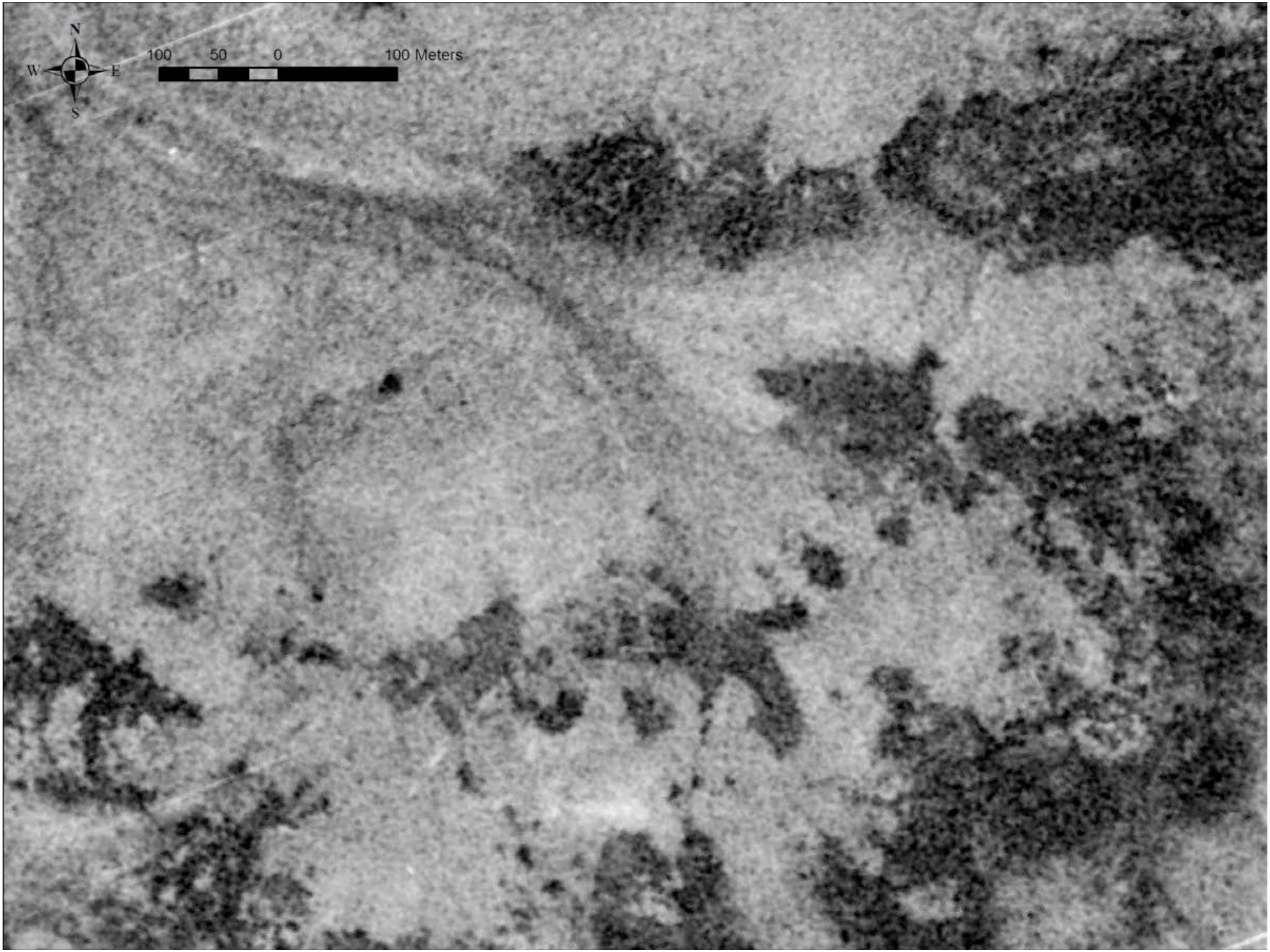


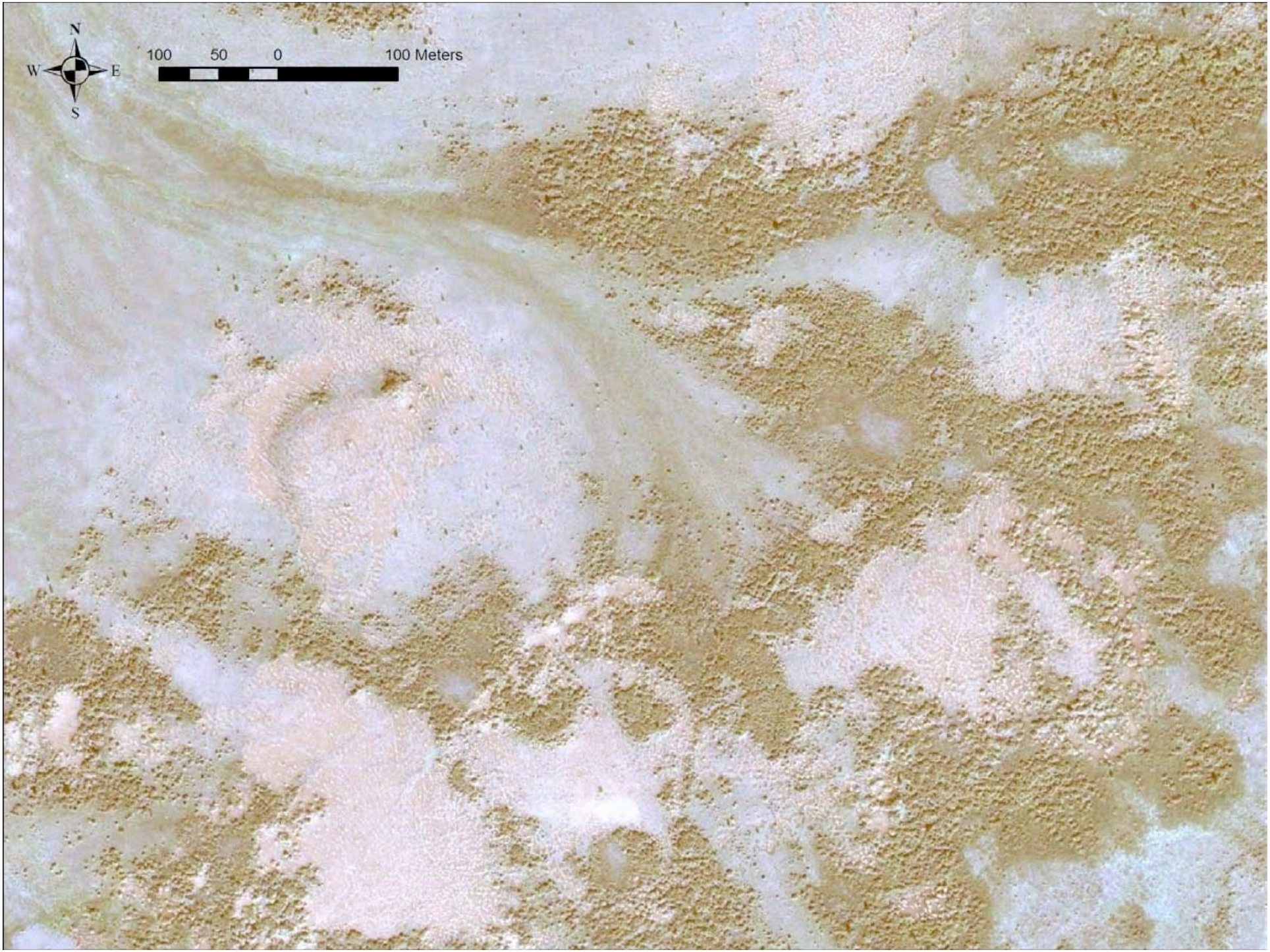
Corona imagery



Corona imagery + georeferenced QuickBird imagery




N
W
E
S
100 50 0 100 Meters


N
W
E
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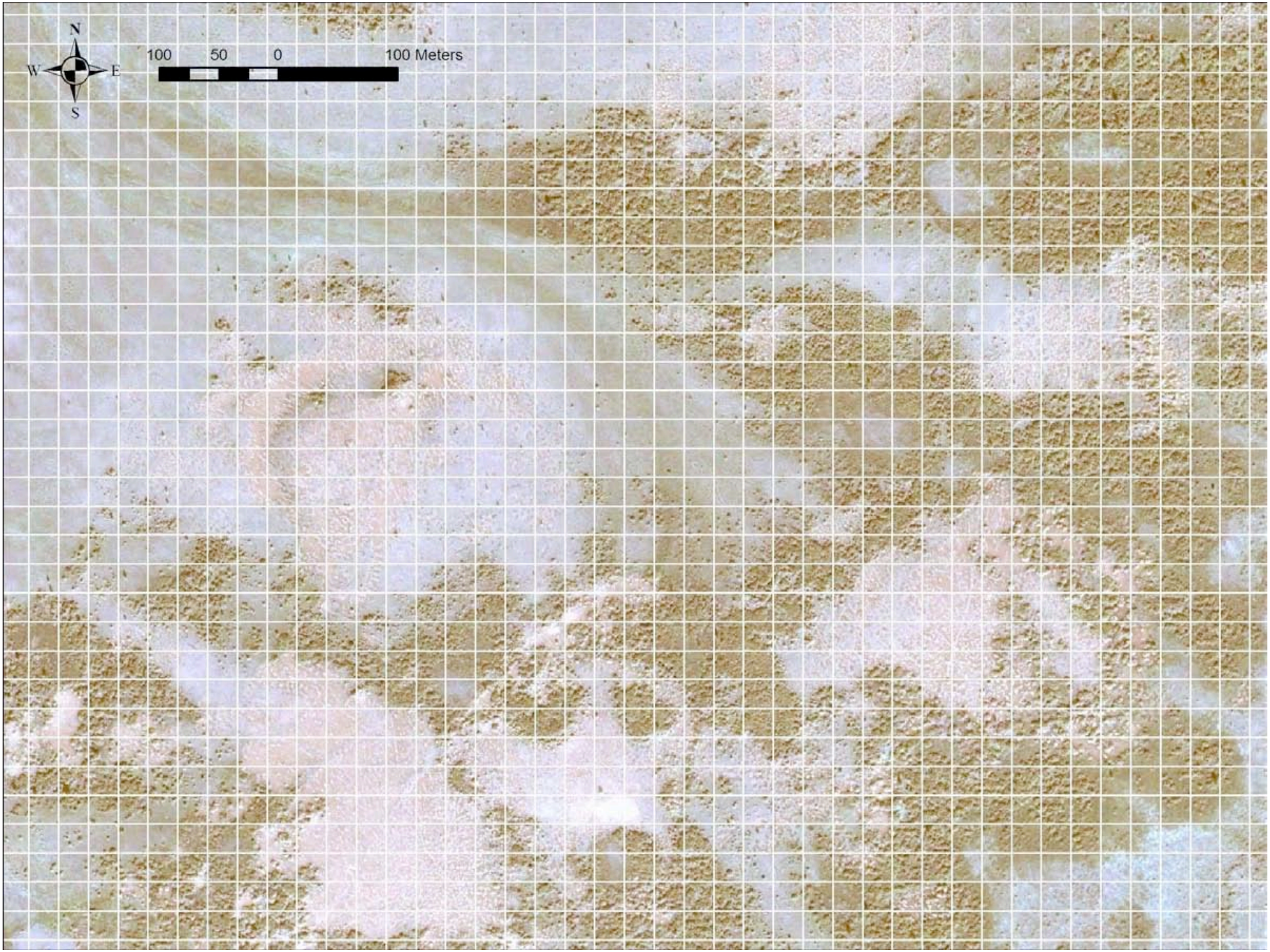
100 50 0 100 Meters


N
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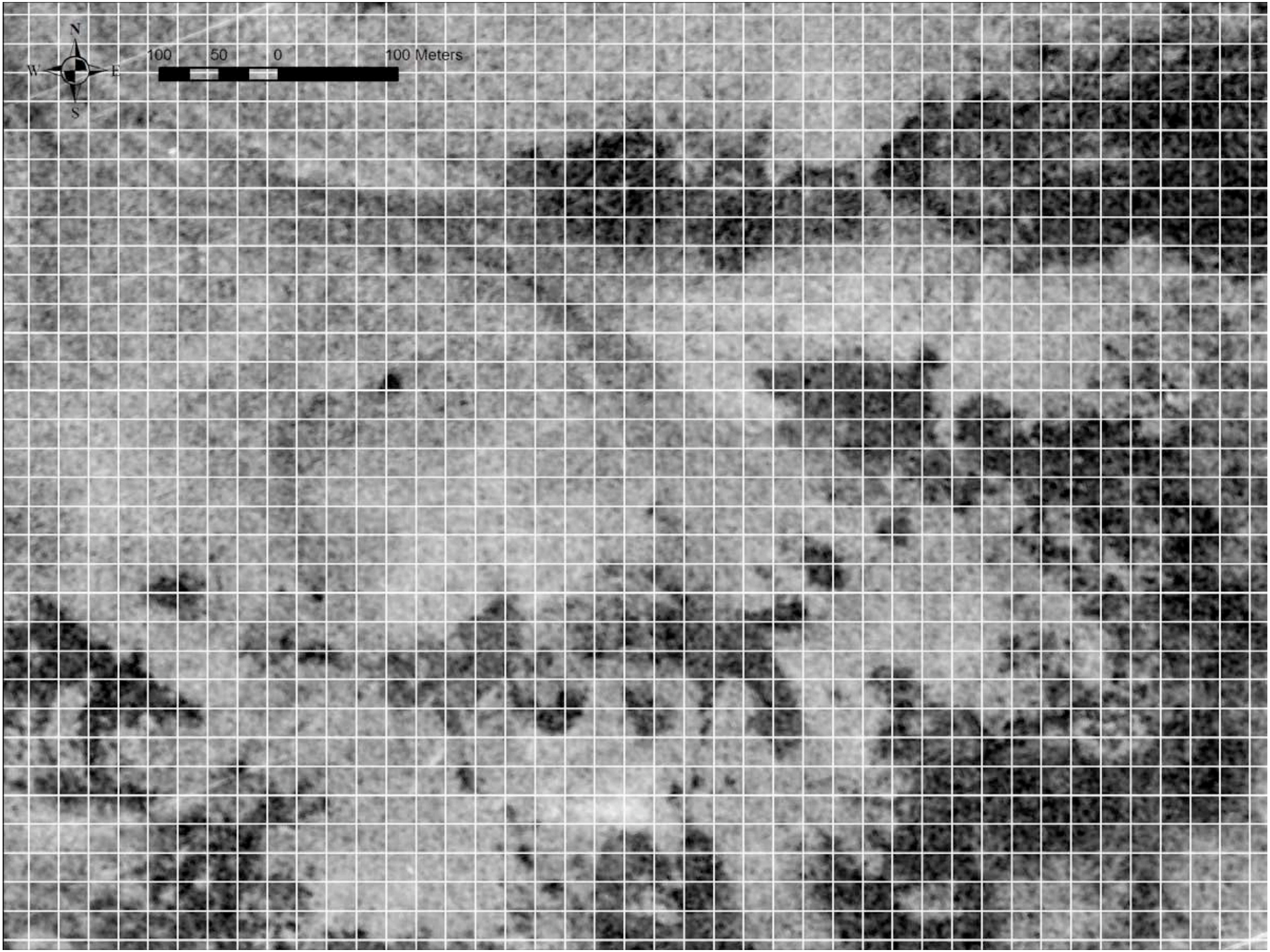
N
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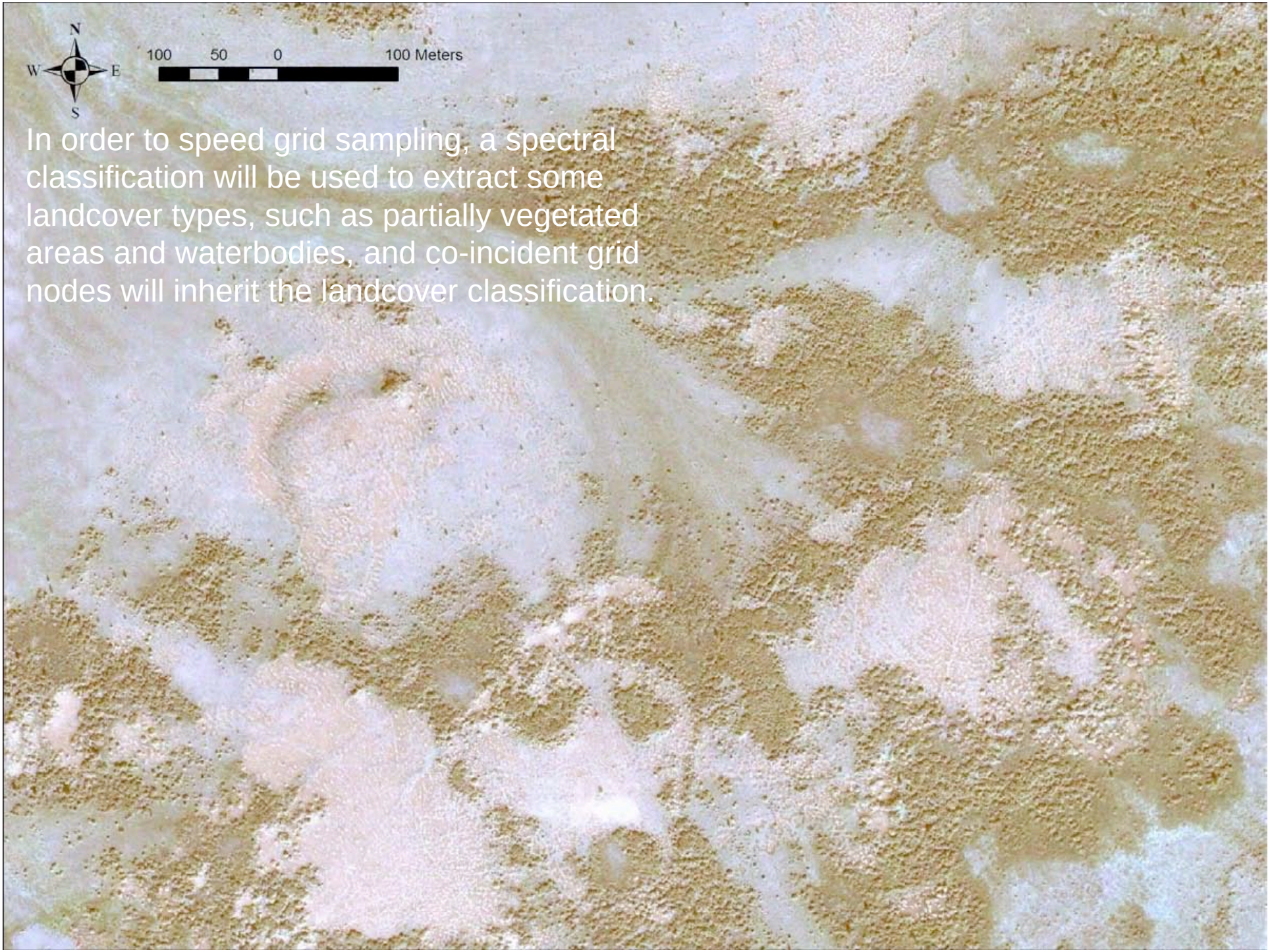
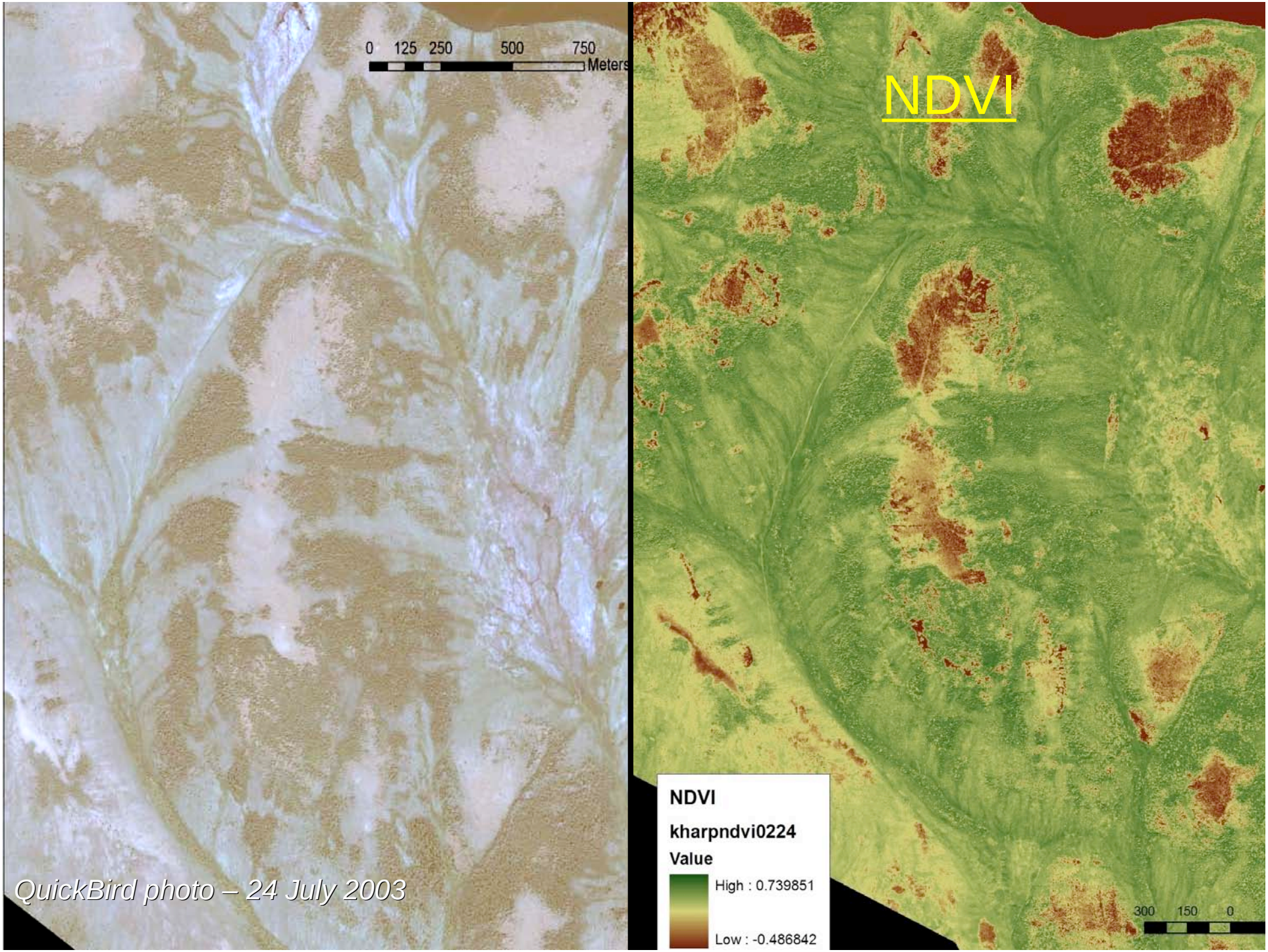
100
50
0
100 Meters



In order to speed grid sampling, a spectral classification will be used to extract some landcover types, such as partially vegetated areas and waterbodies, and co-incident grid nodes will inherit the landcover classification.


0 125 250 500 750
Meters
QuickBird photo – 24 July 2003
NDVI
NDVI
kharpndvi0224
Value
High : 0.739851
Low : -0.486842
300 150 0

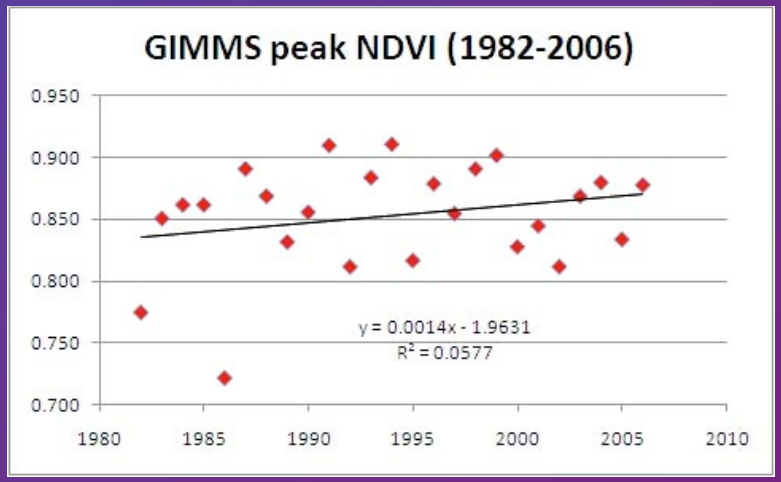
NDVI

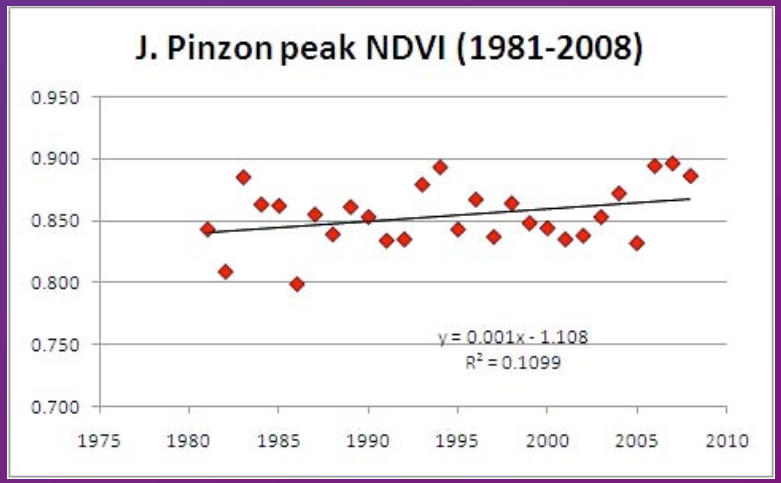
AVHRR pixels co-incident with the Kharp focus area show modest increases in peak NDVI since the early 1980s (~3.5%). We might expect larger magnitude changes in the Kharp focus area.

Landscape heterogeneity is a key uncertainty hindering the interpretation of coarse-scale NDVI time-series.

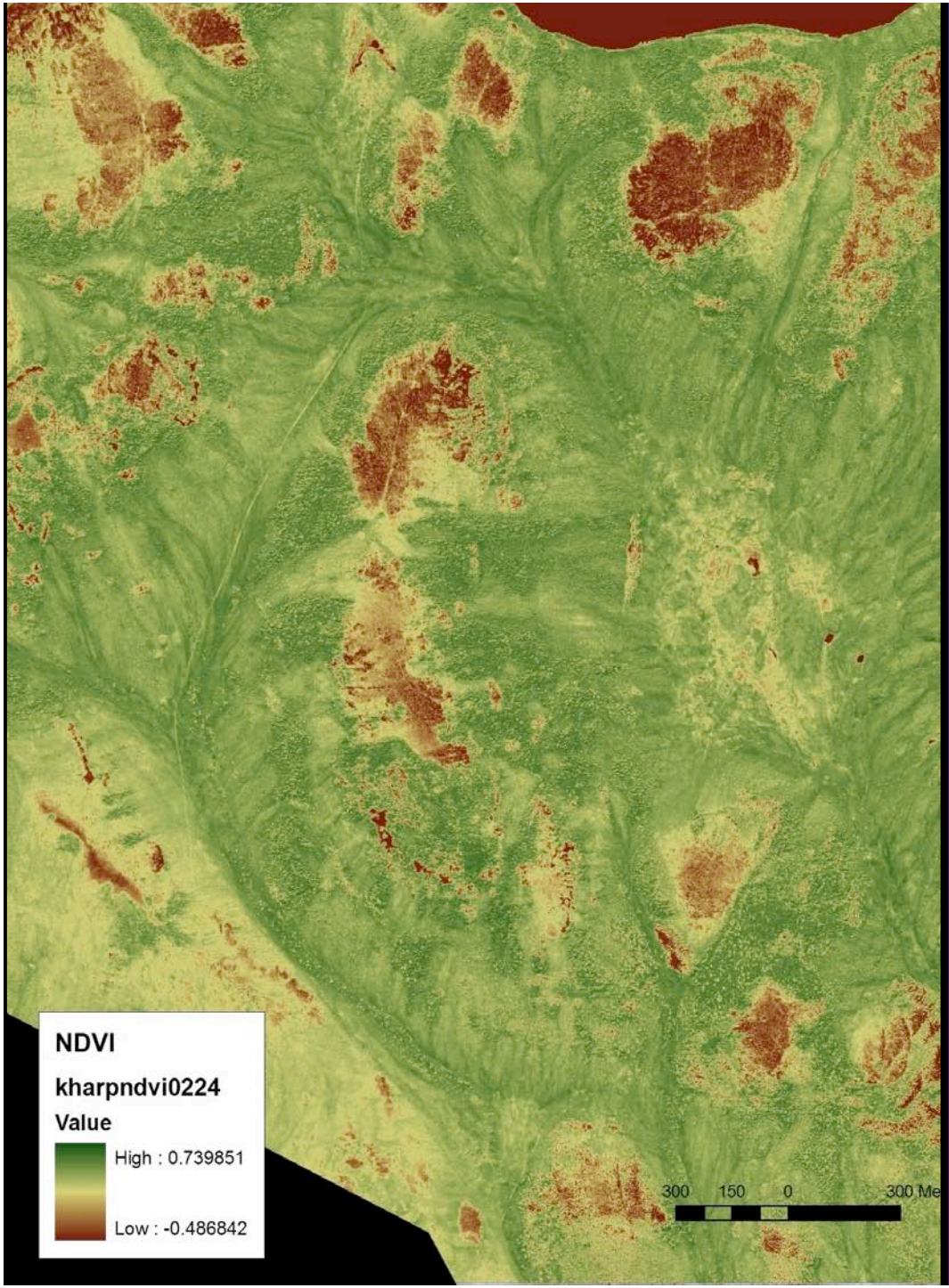
What portions of the landscape are greening?

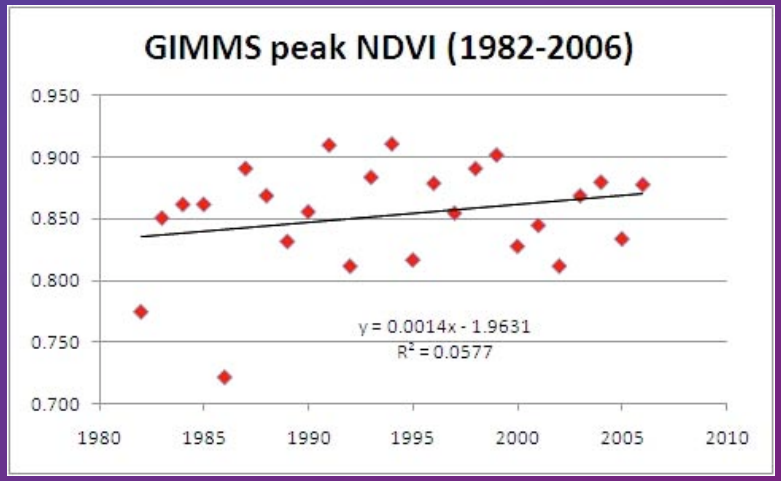
- geomorphic units
- substrates
- disturbance regime

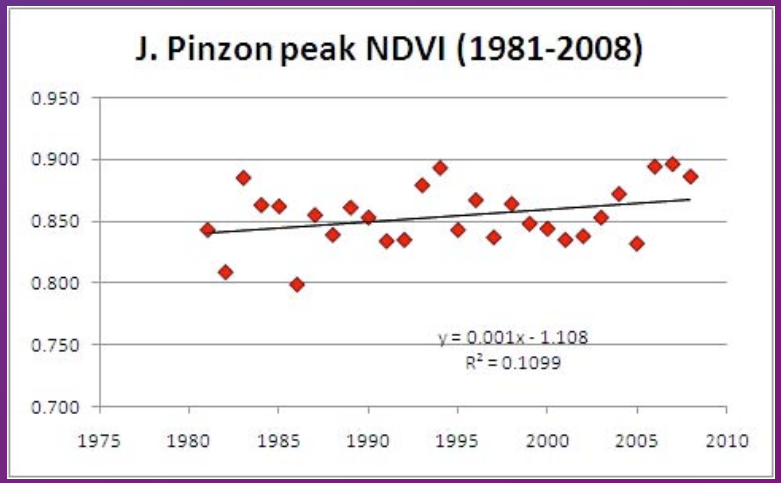




NDVI


NDVI
kharpndvi0224
Value
High : 0.739851
Low : -0.486842
300 150 0 300 Me


GIMMS peak NDVI (1982-2006)
0.950
0.900
0.850
0.800
0.750
0.700
1980
1985
1990
1995
2000
2005
2010
y = 0.0014x - 1.9631
R² = 0.0577


J. Pinzon peak NDVI (1981-2008)
0.950
0.900
0.850
0.800
0.750
0.700
1975
1980
1985
1990
1995
2000
2005
2010
y = 0.001x - 1.108
R² = 0.1099

Scientific questions to be addressed at Kharp focus area

1. What is the absolute and relative extent of shrubification in the Kharp study area since 1968?
2. What are the recent rates of shrubification?
3. What geomorphic units of the landscape are being affected by shrubification?
4. What is the relationship between shrubification and recent disturbance, from the landscape-scale to the meter-scale?
5. Is alder recruitment concentrated on mineral-rich substrates associated with patterned ground?
6. Are patterns of alder distribution (with respect to environmental gradients) comparable to those of shrubs along the Yamal Transect?
7. What are the likely changes to the NDVI signature of the study area that are associated with recent shrubification?

Proposed field methods

1. Determine the year of the Kharp area wildfire using dendrochronology
2. Map substrate types and the burn area by establishing soil pits, and evaluate relationships between shrub cover and substrates using GIS
3. Validate the apparent patterns of alder occurrence on the centers of non-sorted and sorted- circles using ground observations
4. Evaluate rates of alder colonization using dendrochronology
5. Collect ground-based measurements of LAI and NDVI, and relate these measurements to NDVI signatures from satellite-based sensors
6. Establish ~10 relevés to be integrated with the existing dataset from the Yamal LCLUC study.

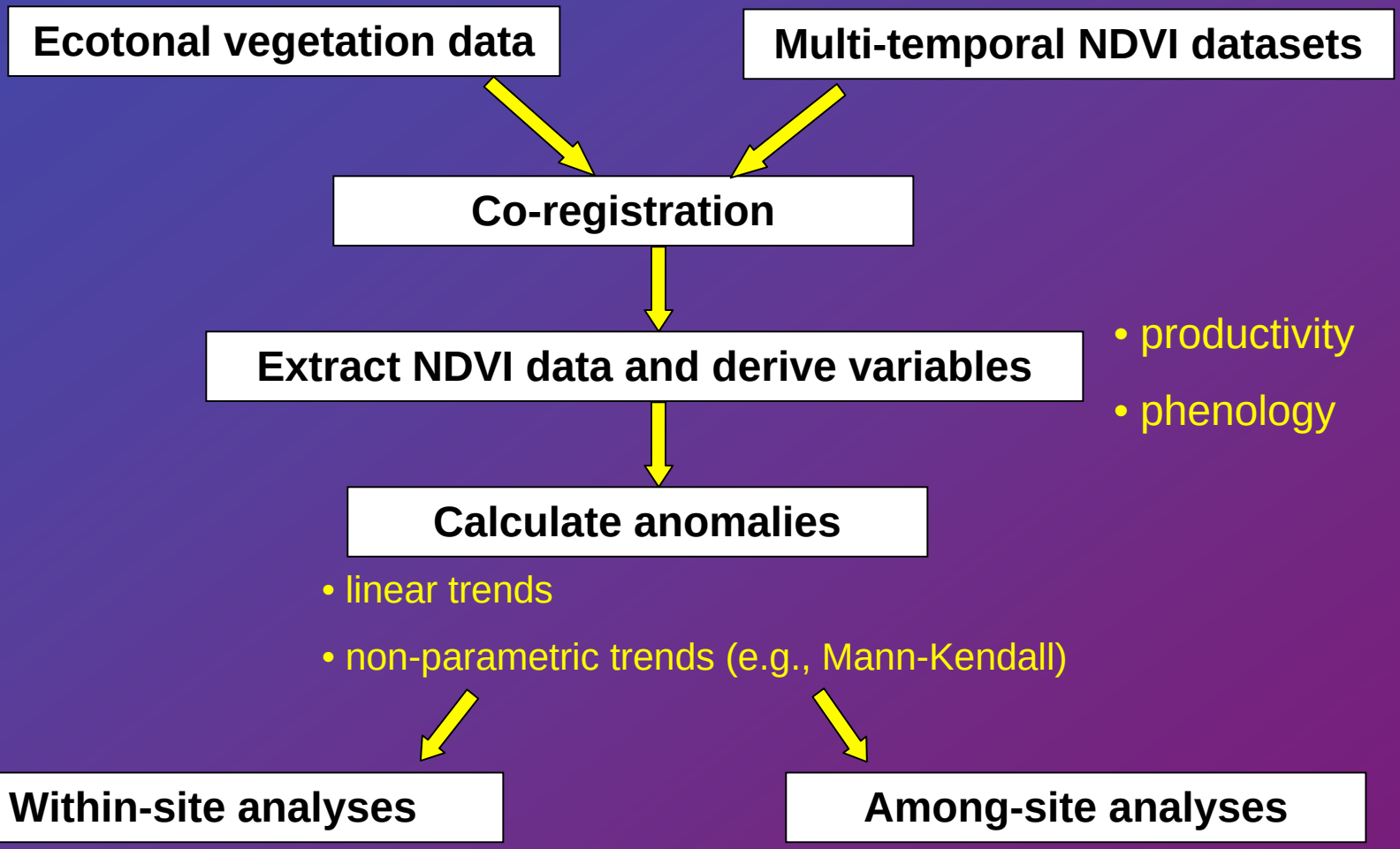
Acknowledgments

Support came from the Department of Environmental Sciences at the University of Virginia, and the NASA/NEESPI Land Cover Land Use Change Initiative, Grant NNG6GE00A; and NSF Grant No. ARC-0531180, part of the Synthesis of Arctic System Science Initiative.

Special thanks to Pasha Orekhov, Gosha Matyshak, and Olga Khitun for coordinating the Kharp field visit in August 2009.

Thanks also go to Shalane Carlson (UVA undergraduate Research Assistant) for producing the spectral classification and heading up the GIS vegetation sampling for the Kharp site.

NDVI Data Flow



compare NDVI anomalies for ecotonal and tundra-dominated pixels within each study site

correlate NDVI anomalies with magnitude and attributes of state-level change among sites

Questions?